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A Case Study On Biofuel Stove Technology: Jatropha As A Biofuel

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Abstract: The study was done on Jatropha bio fuel stove technology. The study deals with comprehensive literature review followed by technical modifications. The wick stove proto type designed for kerosene burning was chosen for the study. The concepts for preliminary design and pre-modifications were drawn on the basis of observations received during testing of proto type to burn with Jatropha oil. Then final modifications of the wick stove were performed technically to make it compatible with burning Jatropha oil. The proto type after modifications contained 1.5 liters tank with three supporting stands. It contained wick burning mechanism exposed with loose 10 single rope cotton woven wicks each of diameter 5 -5.5 mm arranged in a ring. The length of wick was adjusted to 4.5 cm so that the jatropha oil can transport upward easily. The multi-wick mechanism allows for air flow to occur around its enclosed stilt barrel configuration. This has the effect of reducing heat transfer to the fuel vessel and reduces the potential fuel loss in the vessel through evaporation. The cooling effect on the stilt wick reduces the transfer of heat to the fuel vessel, and thus the fuel within the fuel vessel remains below the dangerous flashpoint temperature even after long periods of use. Closer to the top of the enclosed stilt areas become hot during stove use. This has the effect of heating up the air that enters the burning area, thus making the stove more efficient.

Keywords : burners**,** wick stove, modified jatropha pure oil stove, modification

1 Introduction

Currently, due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need to develop alternative energy resources, such as biodiesel fuel. Plant oil is a promising alternative because it has several advantages. It is renewable, environment-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. Therefore, in recent years several researches have been conducted to use vegetable oils as fuel in engines as biodiesel. Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, and sunflower oil, rapeseed oil, and canola oil have been used to produce biodiesel fuel and lubricants. All plant oils that are liquid at ambient temperatures can be used as cooking fuel. In developing countries, kerosene is commonly used as a liquid fuel where plant oils can be used as substitutes. In most developing countries, wood or other biomass is still the primary source of cooking fuel. Electricity remains limited to urban areas. Conventional cooking stoves using fossil fuels are not readily or consistently available, particularly in rural areas, due to the challenges of fossil fuel import and distribution in developing countries. Solar cookers are also not widely available, with given technical and handling challenges. In Nepal, the most well-known liquid cooking fuel is kerosene, composed of hydrocarbon molecules. Plant oils are tri-glycerol of fatty acids, with distinct chemical and physical properties, and different combustion characteristics than those of kerosene. The viscosity of plant oils can be up to 30 times higher than that of kerosene. The flash point of plant oils ranges from 180 to 300ºC, compared to 80ºC for kerosene. This means, the operating risks of kerosene are much higher due to its easy inflammation. Tests found that the hydrocarbon emissions of the Protos plant oil cooker were 370 times lower than that of an open fire with comparable output. The world is approaching an era where energy is increasingly essential. Unfortunately, few developing countries have been able to adjust their energy consumption and production in time. This inability to adapt is responsible for the stagnation of certain forms of development, notably that of agriculture. The search for new and renewable energy sources becomes more and more urgent. Using vegetable oils as fuel substitutes is an interesting departure, in particular, if this consists in non-food oil crops. *Jatropha curcas* is one of them. Research has been done on this plant for over 40 years, particularly during the last world war. But it was abandoned at that time. Perhaps the moment has come to establish a small research program for this plant.

Physical and chemical properties of Jatropha oil

Jatropha oils consist mainly of glycerides of fatty acids. Fatty acids are saturated and unsaturated aliphatic monocarbon acids, whose chain length is between 4 and 24 carbon atoms. Amongst plant oils tri-glycerides are the most common. In these all 3 hydroxyl groups of glycerine are replaced by fatty acids. The variety and specific composition of fatty acids are different depending on the various species of Jatropha. The composition influences physical and chemical properties of the plant oil as well as its burning characteristics. In Jatropha oil, the predominant fatty acids are oleic acid ($C_{18}H_{34}O_2$), linoleic acid ($C_{18}H_{32}O_2$), and palmitic acid ($C_{16}H_{32}O_2$) with 43.1 %, 34.3 %, and 14.2 % of the total mass, respectively. According to the variety, 0.06% up to 6.7 % of the oil can be free fatty acids. Sulfur and nitrogen are likewise present in amounts of 0.13 % and 0.11 %, respectively.

Table comparing the properties of Jatropha oil and kerosene oil

Fuel	Fuel Ignition Point (°C)	Kinematic Viscosity (10^{-6} m²/s)	Gross Calorific Value (MJ /kg)
Jatropha Oil	340	75.7	39.65
Kerosene	50-55	2.2	43.50

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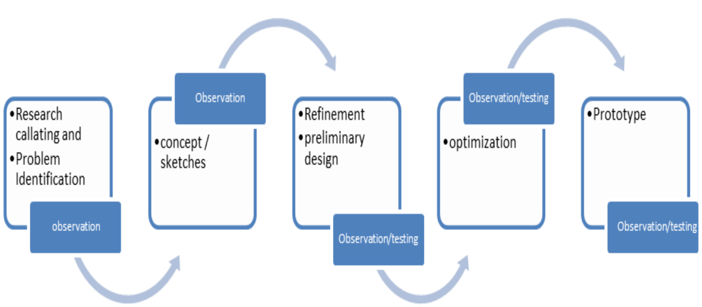
High ignition points of plant oils in connection with extremely high viscosity require special adaptation mechanism of the cooking stoves. Only a few attempts have been made until now to develop cooking stoves with plant oil as fuel. Since viscosity of plant oil is about 30 to 50 times higher than viscosity of kerosene, exact copy of kerosene wick-type stoves are not suitable for the use with plant oils.

Context analysis

About 88 percent of the total energy consumption in Nepal is generated by traditional biomass resources. Out of these biomass resources, about 78% is met by fuel wood only. From the total consumption of 15 GJ per capita, in Nepal, 11.7 GJ per capita is supplied from the fuel wood. The majority of the fuel wood resources are combusted in the traditional wood burning stoves, which emit measurable smoke and fuel gases with major health and environmental impacts in the region and around. The alternate option available to mitigate the wood fuel burning is the Jatropha oil based cooking stove and/or Jatropha seed burning improved cooking stove.

METHODOLOGY

The methodology of this study was developed by the rigorous literature review. In the literature review part, study undertaken by various organizations and individual experts on jatropha, jatropha oil, appropriate technology development, bio fuel appliance and manufacturing process were reviewed. Being research and technology development study, its methodology is based on outcome of design methods rather than usual studio-designed method. The study process involved development of an appropriate design methodology supported by utilizing multiple methods like intervention trials and laboratory scale formulations. These methods were integrated with possible solution which was provided through the modification and manufacturing of a products. The study regarding technologies for end use of jatropha oil consists of formulations and investigations techniques to find out low technology suitability.
The method composed of



The data collection to develop technology and review the existing process and technology was done through secondary sources, especially on electronic communication and various literatures. But the data to support recommendation of technology is obtained from primary sources i.e. test results and observations. The study was performed for the modifications of stove for the compatibility of pure Jatropha oil only. And the modification of kerosene- wick stove taken for the purpose of study was modified by the use of simple mechanical devices.

TECHNOLOGY

The cooking stove in general is classified in two main categories

- Vapor jet burner
- Wick burners

Due to its high viscosity, jatropha oil has difficulty in cooking. Also, presence of other component forming coke and higher ignition temperature of jatropha oil compared to petroleum make it difficult to ignite the fuel. Designs of stoves using the Jatropha seed are based on three different methods. The first uses the solid Jatropha seed kernels as fuel (the TLUD, UB 16 etc.). The second method uses the pure Jatropha oil in modified kerosene stoves with a wick. The third method utilizes the Jatropha oil, vaporized and sprayed under pressure into a specially designed stove, like the ‘Protos’ stove developed by the German Concern Bosch-Siemens. The main challenge of using Jatropha oil in cooking stoves is its high viscosity, which often leads to clogging of the fuel pipe or burner nozzle. Several stoves which have been adapted to or specifically designed for Jatropha oil are shown below (*in Technology development section*). Although it is documented that Jatropha stoves have very low emission levels compared to wood stoves, it is not known yet if the smoke of Jatropha fuel is harmful because of its toxic compositions. Designs of stoves using the jatropha are based on three different methods

1. In first method, solid jatropha seeds, kernels can be used.
2. In second method, jatropha oil can be used in wick stove instead of kerosene.
3. In third method, in pressure stove jatropha oil can be used as stove fuel.

Firstly UB16 has used jatropha woody part, kernels and seed as fuel followed by Anderson’s TLUD stove. Currently, the JI-KO is a successful leading stove for seed and kernels.

Technology development

The Protos	The ‘PROTOS’ plant oil stove was developed in 2004. This unusual stove can be fuelled by unrefined jatropha oil. Except for the burner, this stove can be produced locally, thereby creating employment. Over 500 ‘‘Protos’’ stoves had been tested in the Philippines, India, Indonesia, South Africa and Tanzania. Currently the inventor/producer company has pulled back its project. It is expensive, as it costs approximately 45 USD Blue print to reproduce is available.
Servals Automation Jatropha stove	Pressure stove using vapor jet burner

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	Using water, kerosene and Jatropha oil (triple filtered). An oil-and-water stove and modifications of existing models of kerosene cook stoves. While the oil-and-water model did function adequately with Jatropha oil, its size and relative complexity make it applicable only for large kitchens like schools or restaurants. Still in R&D phase. Not available for consumer.
Kathmandu University Jatropha oil Stove	Pressure stove using vapor jet burner. Successfully tested up to 30% blend. Not available for trial. Not fit for pure jatropha oil.
Institute of Engineering plant oil stove	Pressure stove using vapor jet burner, tested with kerosene – oil blending. No more functioning.
Sutec, Tanzania	The wick stove. Made with flat wick. External oil reservoir. Prototype successfully tested.
Matt's Stove	Pressure stove, problem with pre heating chamber. In R&D phase.
Lodge tech stove	The Wick stove. Successful. Available in market, but costs around 75 USD - expensive

THE JATROPHA PURE OIL STOVE

Mostly in the rural areas of Nepal conventional fuels like fuel wood, charcoal and petroleum products are used for domestic purposes. For stoves, the conventional fuels in most rural areas are fuel wood, charcoal and petroleum. By introducing alternatives like plant oils such as, jatropha oil for cooking, the use of conventional fuels could be strongly reduced. Potential users of the jatropha oil are those persons who currently buy their fuel (kerosene) in areas where there is no free alternative available. As the pure jatropha oil has high viscosity and ignition temperature it cannot be used in kerosene burning stove. But the production of successful vapor jet burner stove i.e. pressure stove has stopped and other Pressure Stove for pure oil are still in development phase, so there is no commercial utilization of jatropha oil. The best option to replace the fire wood stove with a Jatropha oil based stove may be pressure stove or those using wicks. The Kathmandu University, Servals Automation Cooperation India and other institutions are still investing in research and development. To use pure Jatropha oil for cooking only wick stove is left which fulfill the contextual demand criteria being low cost, effective for cooking, without a dramatic change in food taste, user friendly, ease in local manufacture.

THE WICK STOVE

Previous research has shown wick stove as one of the best option for use of jatropha oil and it is also easily available in Nepal as well as accepted by the community. In Nepal the presence of kerosene wick stove is decades old. However, the cooking habit and efficiency of vapor jet burner had overshadowed it. Thus, during the trial and testing phase wick stove was used for jatropha oil because of the following criteria:

- Availability in Nepal. Some workshops are still producing this relative simple and cost efficient technology.
- It is a relatively old and long proven technology.
- Modifications for bio fuel usages are relatively simple.

However there are some constraints, which have to be considered as,

- The technology has partly been replaced by the pressure stoves which are more fuel efficient, even if they are more expensive and more complicated in handling.
- Pressure stoves use vaporized gas for the burning process, which results in a much more complete combustion with less emissions and a blue flame compared to a common wick stove.

There have been many efforts globally so far to manufacture a professional and marketable bio fuel pressure stove, only one stove can be considered feasible for the introduction in the market, which is the “PROTOS”. This stove was designed by one of the biggest German concern called Bosch-Siemens-Hausgeraete. In cooperation with GIZ, some millions of Euros have been invested to design the “PROTOS”. For about 5 years it has been manufactured in Jakarta, Indonesia, however recently (in 2012) the production has been stopped due to a lack of market opportunities and a problem in oil supply. This sample obviously shows that vaporizing pressure stoves are not yet ripe for the use in case of study. However, studies at the Kathmandu University and the Centre of Energy Studies in Kathmandu have shown t common pressure stoves can be used with a blend of up to 30 % bio fuel and kerosene. This option should be considered as technological concepts for further development of pressurize bio fuel stoves.

DESIGN/MODIFICATION FACTORS

The study was based on the modifications principles proposed by Whitney Veigas, suggests the four factors of a successful design as: “function, aesthetics, cost and technology”[1].
Following steps have been undertaken during the design process:

- Problem identification
- Observation and testing
- Re-designing and testing
- Follow-up

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THE MODIFIED WICK STOVE

General description

The 1.5 Liter Size Multi-wick stove is a barrel shaped stove that has its three support legs caging a flat cylindrical-shaped fuel vessel with the wick burner mechanism exposed. This multi-wick/'range wick' stove is aimed at low-income technology for domestic cooking use. This stove can be used for either indoor or outdoor cooking. The fuel vessel is electroplated. The finishing on this stove gives the stove an appealing clean aesthetic. The stove has a round shaped multi-wick configuration with 10 wicks arranged in a ring each of diameter 5mm. The 10 single rope-like wicks are cotton woven. The multi-wick mechanism allows for air flow to occur around its enclosed stilt barrel configuration. This has the effect of reducing heat transfer to the fuel vessel and reduces the potential fuel loss in the vessel through evaporation. The cooling effect on the stilt wick reduces the transfer of heat to the fuel vessel, and thus the fuel within the fuel vessel remains below the dangerous flash-point temperature even after long periods of use. Closer to the top of the enclosed stilt areas become hot during stove use. This has the effect of heating up the air that enters the burning area, thus making the stove more efficient.

OBSERVATIONS AND MODIFICATIONS

Observations

First the stove was filled with kerosene, ignited and observed to make comparison. Then the stove was filled with pure jatropha oil and ignited. Once stove started burning the key problem found out were:

a. No rapid Ignition

The ignition taking place was lengthy.

b. Transportation of fuel

The fuel tend to transport with wick were very much fine up to <5 cm, once it cross 5 cm it got slow and at 7 cm there was almost no fuel.

c. Sufficiency of fuel

The standard wick, once placed in fitting tube, oil transported by capillary mechanism in the gap got congested which result less amount of fuel to burn up.

d. Coking up

Wicks coke up quite quickly. They form coke in the burning zone which prevents satisfactory combustion.

Modifications

After observations, problem analysis and several modifications, the final modifications made were:

a. Soaking the wick in oil prior to ignition improved ignition time and took similar time as it took with kerosene.
b. By placing a wick in a loosely fitting tube, transport properties were improved considerably.
c. The length of tube (wick holder) was cut to make 4.5 cm (from oil reservoir to fire zone).
d. The standard round wick of 6.3 to 6.5 mm placed in a loosely fitting tube (tube diameter = wick +1mm) comfortably transport oil 4cm upwards to allow for a satisfactory adjustable flame at the top.
e. It took longer time for a wick to coke up if the tube into which it is placed was wrapped with overlapping edges.
f. The removal of coke was not difficult; it was simply knocked off from the top of wick.

RESULTS AND DISCUSSIONS

The modification of the existing kerosene wick stove was done for the compatibility of Jatropha oil. The bio fuel consumption for a given wick and a given setting was about the same as for kerosene. The brightness/color of a flame for a given wick and a given setting was about the same as for kerosene. The problem with adapting a kerosene stove to plant oils is due to varying viscosity than in terms of purity of the oil. Jatropha oil is too thick at room temperature to travel through wick, and it was difficult for the oil to cross 5 cm, rather than the 10 to 15 cm required to efficient burning. Once the problem was pointed out, the modification was made with wick length and with wick holder. As the wicks are not able to maintain the oil supply in the same way the oil burns at the upper end of the wick. Consequently the wicks catch fire and burn and the flame extinguish after a short time of burning. The prototype wick stove is still in their nascent stage, even the feedback from some of the initial community acceptance done, confirmed from literature review, urges the demonstration is rather positive. It can be assumed for slow cooking purposes (preparing fodder for animal and traditional food i.e.Dhindo, Dal-Bhat, etc. will be fulfilled by this stove. Before bringing this type of stove into use or disseminating it in any community or use, an emission test must be carried out (preferably following the UNFCC stove protocol). If a public acceptance survey is positive and the emission tests are acceptable, the setting up a small manufacturing unit might be considered. Since pure jatropha oil has high viscosity and ignition temperature, making it difficult to be used in normal kerosene stove and the vapor jet burner stove (Pressure Stove) for pure oil is still in development phase. Wick-burner kerosene stove can be used for jatropha oil with modifications on oil transportation length and capillary. This does not produce any bad odor and also soot emissions are less than biomass stove which can be done by adjusting fuel to air ratio.

CONCLUSION

As jatropha oil possesses various potential uses, it is regarded as the best option compared to petroleum oil. In case of Nepal, where 80%of energy need is fulfilled by biomass i.e. fuel wood, Jatropha plant can be a major source of biomass energy. However, the pure Jatropha oil can be used as a renewable source in the stoves to meet the required energy demand.

Besides, the use of jatropha seed for fuel, Jatropha possesses several potential uses. It can grow in harsh soil condition and can be planted on bare and eroded land which reduces the potential risk of erosions. Likewise, the end products of jatropha plant such as, oil, residual biomass, seed kernels have other likely uses. Pure jatropha oil can be used in the manufacture of commercial high value medicinal soap as Jatropha shows great anti-microbial property. The residual biomass remained after pressing of seed for oil obtained as seed cake

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can be used as direct compost in the field. Along with this, the seed cake can be used in vermin composting. Although Jatropha contains *phorbol ester* as a toxic component, it can be used as compost. Because the role of calcium signaling in activation of both, innate and adaptive immunity which is basically important in coelomocytes. The *phorbol ester* present in the seed cake of Jatropha can attenuate the increasing requirements of calcium ions in the body of earthworms[2]. Similarly, the remaining biomass can be used as a source for briquetting. The dried biomass of Jatropha, along with seed kernels and seed cake when pressed with binding material can be used as briquette. Thus, Jatropha plant can be designated as a source for multi purpose uses.

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